tion, and change inclination. Such a straight segregation of clean water shows that no self-attraction of the suspended solids can be the cause. In a recent point of view it looks like a liquid crystal arrangement of water expelling the powder as foreign matter, especially when we remember the habit of ice crystals in very thin plates. The question then arises, Are all these emulsion figures due to the clear liquid segregating and expelling the suspended matter?

W. M. FLINDERS PETRIE.

MODERN FORMS OF RONTGEN-RAY TUBES.

IN spite of many obstacles, medical technique in the application of Röntgen rays has made steady progress during recent years. But there still remain certain primary difficulties which are often a source of hindrance and confusion. The demand for a more trustworthy method of working than exists to-day is the natural outcome of wider radio-therapeutic experience, but what is required above all is an accurate means of measuring the output of the tube.

The solution of this problem clearly requires that we shall have at our disposal an apparatus capable of emitting a specific type of ray in definite quantity; and were it not for some experiments by Dr. Lilienfeld, and more recently by Mr. Coolidge, of New York, there would be little prospect of actually realising this result in practice. I shall refer to their work more in detail later.

Meanwhile, it is worth noticing that the modern X-ray tube, with all its imperfections, is a triumph of craftsmanship. It is the result of numberless costly and difficult experiments carried out by manufacturers and others to meet a demand which grows more exacting every year. The collection of historical X-ray tubes brought together some time ago by the Röntgen Society, and now on view in the Science Museum at South Kensington, contains the first bulb which embodied the chief features adopted universally up to the present time in the construction of X-ray tubes. That bulb was made by Prof. Herbert Jackson in 1896, and measures only 3 in. across. The diameter of those in use to-day is, however, usually twice or three times as great, the electrodes being heavy and the vacuum carefully adjusted.

The successful working of the apparatus depends so largely upon this last factor that decrease in pressure of the residual gas, invariably accompanying prolonged use, has to be compensated for. The devices employed for regulating the vacuum may be divided into three main classes, viz., those:—

(1) In which a few discs of mica, a piece of carbon or asbestos, etc., fixed within the bulb, offer an alternative path for the discharge, so that gas is, when necessary, liberated by the heat generated, as the electric current follows the line of least resistance.

(2) In which a fine palladium tube stopped up at one end has a small tubular extension of platinum soldered to it for sealing into the X-ray bulb. A gas flame brought near so as to heat the palladium enables hydrogen to enter by osmosis, and so lower the vacuum. All the tubes used in the X-ray treatment cubicles at the London Hospital, for instance, have these "Osmo" regulators.

(3) In which air is allowed to enter through the pores of a piece of unglazed porcelain, which is usually sealed with mercury until by a pneumatic contrivance it is momentarily uncovered.

But none of these methods is free from objections. The regulation is generally too insensitive. The tube often outlives the supply of gas from the first sort, and the others are only trustworthy in skilled hands. The mica disc regulator is shown in the diagram (Fig. 1), which otherwise is self-explanatory.

Messrs. C. H. F. Muller describe some eighteen types of tubes of this character in their recently published catalogue, and give precise instructions for the adjustment and use of each kind. There are in addition five coloured plates showing the appearance of X-ray bulbs in action, and a great amount of useful information besides. Fig. 2 (Muller) may be taken as representing a typical example of modern heavy discharge X-ray tube.

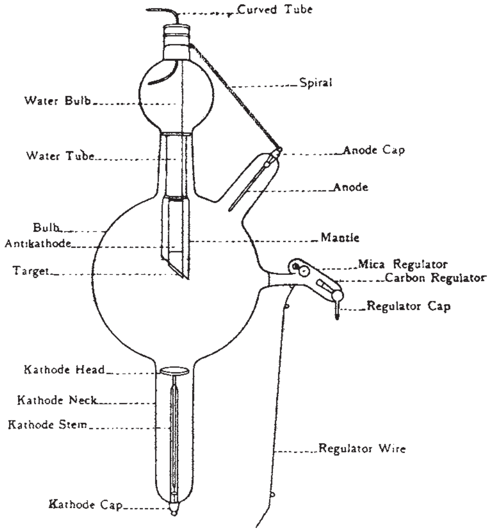

FIG. 1.—Showing the terms in common use to denote the different parts of the instrument.

The cause of the disappearance of gas with prolonged use has given rise to much speculation. It has been suggested that the ions produced by the discharge are driven actually through the walls, and so escape; there is proof at least that the glass takes up a large part of the residual gas under these conditions, and that lead glass absorbs more than Jena.

Since the degree of vacuum controls the resistance of the tube, and this in turn determines the current that passes with a given potential difference between the electrodes, it is evident that the pressure of the residual gas is the chief factor which defines the type and quantity of rays to be obtained. Moreover, the kathode itself must carry a minute trace of gas to facilitate the transfer of electricity from the metal to the surrounding space. Further, the great heat often generated at the antikathode raises the temperature of the walls to such an extent that gas is set free there, and the balance of working conditions upset. A new tube, in fact, generally requires "maturing" until its vacuum when at work will keep practically constant, and yet be neither too high nor too low. This calls for much care and patience on the part of the operator. A bulb may in this way be coaxed to carry 5 milliamperes for hours at a stretch, and be of great service in "treatment." In most cases, however, the current does not exceed 2 milliamperes for that purpose. But in radiographic work the usual practice is to employ a heavy current—20 milliamperes—for a few seconds or even a fraction of a second. The length of exposure is, of course, determined by a number of considerations, but with such a large current it cannot exceed a few seconds on account of the enormous heat generated at the antikathode by the impact of electrons.

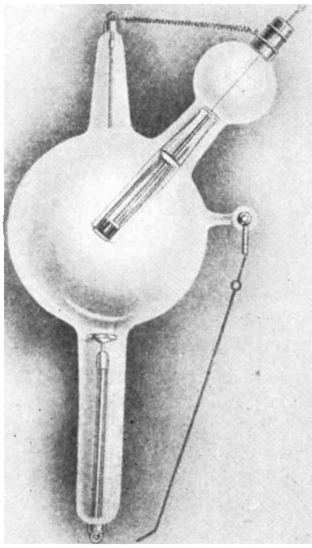
FIG. 2.—Heavy-discharge X-ray tube.

The same difficulty is met with in the treatment tubes, quite apart from the disengagement of gas, for a longer exposure has to be given now than would be necessary if more current could be carried with regularity and safety.

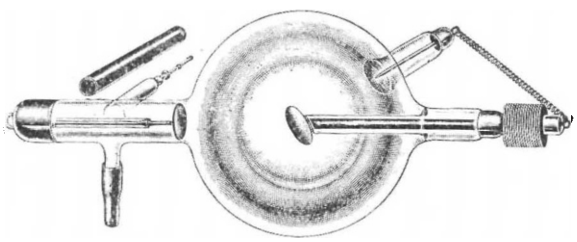
FIG. 3.—Heavy discharge radiator tube.

Under existing conditions the antikathode stem is usually made hollow, so as to enable water or air to flow in and carry off the heat, or an actual radiator may be fitted, as shown in Fig. 3 (Cossor). The osmosis regulator is also represented in the same illustration. Otherwise, even the hardest substance used as target would melt or become pitted by the impinging electrons. As an example of what occurs, the photomicrograph (Fig. 4; for which I am indebted to Dr. Rodman) of a plate of platinoid-nickel which has served as target may be of interest. In all cases except for very light work, the antikathode is made of stout copper faced with platinum-iridium or pure iridium, tantalum, etc., at the place where the kathode rays impinge upon it. The uncertain variation of vacuum, together with the development of excessive heat at the antikathode, constitute the most serious objections to the present system of working. The first difficulty especially hinders progress towards the attainment of an accurate method of measuring or describing the radiation dealt with, for it may change from day to day, or even during an exposure. But there are, in addition, many minor ailments which develop with the age of the tube. Thus a deposit comes gradually upon the inner surface of the walls. It is mainly metallic, and occludes gas; but it also provides electrified areas which disturb the normal streams of electrons. Occasionally, too, patches of bright fluorescence appear on the glass, due to specks of foreign matter sticking to the kathode. The direction of the discharge will sometimes reverse in the tube from no apparent cause. Indeed, the behaviour of a bulb is so erratic at times that a superstitious person might be excused for regarding it with distrust.

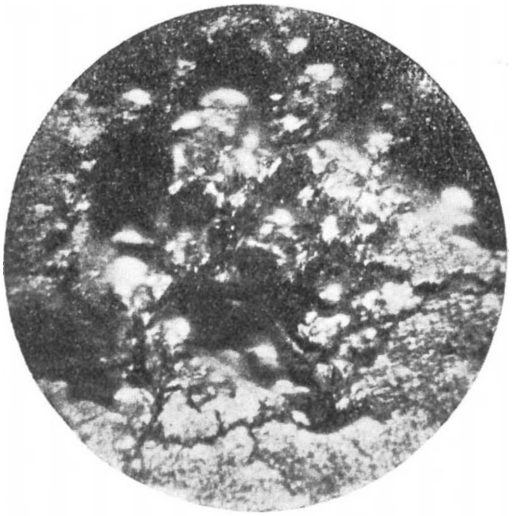
FIG. 4.—Photomicrograph of eroded target.

However, with care and experience, and in spite of many disadvantages, splendid work is being done with this super-sensitive apparatus. But it is none the less necessary to make every effort towards placing X-ray therapeutics upon an accurate quantitative basis, and to simplify the technique. With existing appliances the prospect of so doing is remote indeed.

But we are on the eve of great improvements! Dr. Lilienfeld, of Leipzig, has already constructed a Röntgen tube which is so highly exhausted that the residual gas plays no part in the working of the apparatus. The first description of this new departure was given in the *Fortschritte auf dem Gebiete der Röntgenstrahlen* for June, 1913, and more recently a further account has appeared in a later issue (Band xviii., p. 256).[1]

Dr. Lilienfeld creates an electric field in the neighbourhood of the antikathode between an aluminium tube and a white-hot wire. The working potential difference is then applied to the main electrodes and a discharge immediately passes. Since the current taken by the tube depends upon the temperature of the so-called priming device, the operation is under control.

But Mr. Coolidge[2] has simplified this design still further by placing a small spiral of tungsten at the centre of the kathode; heating this by an independent current he obtains a supply of electrons which are repelled and driven against the target with such speed as to produce copious X-rays where they strike. Thus, given a powerful induction coil and noting that the bulb is so well exhausted that 100,000 volts at its electrodes produce no discharge, the spiral is heated and the current that then passes is simply a function of the temperature. Variation of the potential difference would mean an alteration of the speed at which the electrons are driven against the target. The *quality* of the X-rays produced can therefore be varied, irrespective of their quantity. This is not possible with any other type of X-ray tube. Its importance cannot be over-rated. It places in the hands of X-ray operators an instrument of precision. Many questions are still outstanding; it is not even claimed yet that this apparatus is beyond the experimental stage. Meanwhile, however, it may be of interest to point out that the Coolidge tube has already given some remarkable results. The most successful bulb so far made measured 18 cm. in diameter, and was blown from German glass; it carried a current of from 1·7 to 36 milliamperes with the spiral heated to a temperature varying between 2010° and 2240° absolute. It was run for fifty minutes continuously on one occasion with 25 milliamperes passing. There was, of course, great heat developed in the antikathode, but the regularity of the action seems to have been unaffected. No fluorescence appeared upon the glass of this bulb, and the starting and running voltages were identical. The tube is also its own "rectifier," and may be run off an alternating circuit without any additional device to suppress one phase.

The prospect of being able to speed up the electron so much that it may give rise to a radiation with a wave-length equal to, or even shorter than, that of the Gamma ray from radium, offers great therapeutic possibilities.

It remains so far to improve the means of supplying electricity to the tube that a steady potential difference may be maintained at its electrodes. Then, since reversal seems impossible with the Coolidge system, it should be feasible to produce pencils of approximately *homogeneous* X-rays in definitely measurable *quantity* and of a *quality* expressed in terms of the coefficient of absorption in some agreed substance.

An attempt to construct a tube upon the new principle is at present being made in the physics laboratory of the Cancer Hospital, and experiments will be taken in hand there as soon as possible to test the types of ray obtainable by this means.

CHARLES E. S. PHILLIPS.

THE SICILIAN EARTHQUAKE OF MAY 8.

THE earthquake which visited the south-east flank of Etna on May 8 is evidently one of the strongest of the local shocks which occur so frequently within the bounds of the volcano. Unlike the Messina earthquake of 1908, the shock was heralded by many slight tremors in the surrounding district, several having been felt every day since April 25. But for these warnings, the loss of life might have been far greater than it was, though more than 150 persons are reported to have been killed and about 500 injured. The villages of Linera, Passapomo, Pennisi, and Zerbati are completely ruined; Cosentini, S. Caterina, and S. Maria Vergina are half-destroyed; while about a dozen other villages from Zafferana and S. Venerina on the north to Trecastagni on the south are seriously damaged.

The epicentre of the earthquake is clearly at and near Linera. The details at present known are insufficient to determine the boundary of the meizoseismal area, but its greatest dimension can scarcely exceed two or three miles. For the same reason, nothing more is known as to the extent of the disturbed area beyond the fact that it was small considering the violence of the shock near the epicentre. Probably the disturbed area is far less than that of some of the weakest of British shocks. This alone proves how rapid was the decline in intensity from the central region. At Acireale, only four miles south of Linera, the damage to property was slight. At Catania, seventeen miles to the south, the shock was felt, and excited some alarm. These two facts—the great intensity near the epicentre and the rapid decline in strength outwards—show that the focus must have been quite close to the surface.

It is, however, in its relations with previous earthquakes in the same region and with the eruptions of the neighbouring volcano, that the interest of the earthquake chiefly lies. Two and a-half years before, on October 15, 1911, a similar, though less destructive, earthquake occurred in the immediate vicinity. The meizoseismal area in this case was a narrow band, four miles long and about a-third of a mile wide, extending from Fondo Macchia to Guardia, and passing about a mile and a-half to the north-east of Linera. On this occasion twelve persons were killed and forty-eight injured. On July 19, 1865, the same district was ruined by an earthquake, by which seventy-four persons were killed and fifty-six injured. Other shocks visited the same or neighbouring villages on July 11, 1805, and Janu-

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[1] A good summary is published in the *Archives of the Röntgen Ray*, for February, p. 340

[2] *Physical Review*, December, 1913.